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New Bedford

225118

Relative Risks posed by Polychlorinated Biphensyls, Polychlorinated Dibenzodioxins and Dibenzofurans in New Bedford Harbor sediments.

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This preliminary evaluation is intednded to determine the relative risks posed by the contaminants found in sediments from New Bedford Harbor based on the chemical analyses provided by the Environmental Research Laboratory at Duluth, Mn to the New Bedford Harbor Project Manager by letter of February 27, 1987. The contaminants reported in the letter include polychlorinated biphenyls (PCBs), polychlorinated dibenzo dioxins and dibenzofurans, PAH, TOC and Metals. Concern has been expressed because the analyses showed the presence of dioxins and furans in the habor sediments in addition to PCBs. The Regional office was concerned on whether or not dioxins and furans will be the compounds posing the highest risk relative to other toxic compounds including PCBs found in the sediments.

The evaluation provided here is to estimate the relative risks posed by PCBs, and dioxins and furans since they are the compounds of most concern. The relative risks for the other compounds can be quickly assessed by following the methodology provided here, but are not estimated as part of this evaluation. The absolute risks associated with the presence of each type of the contaminants are not estimated because it will require additional site-specific data.

To compare the risks for PCBs, and dioxins and furans, four exposure pathways are considered, and the corresponding risks can be estimated by the following formulae:

- Dermal Absorption after Contacting Sediments by Swimmers

  Risk = (Sediment concentration) (Sediment contact Rate)

  (Exposure period) (Absorption Factor) (Potency Slope)/ Weight of Individual

- Release of Sediment Contaminants into Water, and Absorption of Water Contaminant thru Skin

  Risk = (Concentration in Water) (Water Contact Rate) (Exposure Period) (Absorption Factor) (Potency Slope)/ Weight of Individual

- Fish Intake following Bioaccumulation in Fish

  Risk = (Daily Fish Intake Rate) (Concentration in Sediment) (BCF)

  (Exposure Period) (Absorption Factor) (Potency Slope)/ Weight of Individual

° Inhalation of Contaminant Vapors released from Sediment to Water and from Water to the Air

Risk = (Ambient Air Conc.) (Air Inhalation Rate) (Exposure Period)

(Absorption Factor) (Potency Slope)/ Weight of Individual

The relative risk can be estimated by taking a ratio of the risks for PCBs, and dioxins and furans. In taking this ratio, the common factors such as exposure period, weight of individual, or water contact rate cancel out each other. Hence, the relative risks can be determined by taking a ratio of parameters left out such as contaminant concentrations and potency slopes. The specific ratioing technique follows later.

The potency slope for 2,3,7,8 - TCDD is developed by EPA. Other dioxin and fruan compounds are given relative potency factors. The factors listed in an EPA publication (EPA-450/4-84-014g) dated April 1986 are used. These factors for dioxin and furan homologues are shown in the 2nd column of the attached table. The total equivalency factor (TEF) for dioxins and furans can be obtained in two steps: First, the concentrations in sediment are multiplied by the relative potency factor and these multiplications are summed; second, the summation is divided by the total concentration of dioxins and furans.

As shown in the attached table, the total concentration of dioxins and furans ranges from 2,318 to 16,863 pg/g with the corresponding TEF of 0.0015 and 0.018 respectively. The concentration relating to the highest toxicological importance for dioxins and furans corresponds to the sediment from NBH-14 with the total concentration of 16,863 pg/g and the TEF of 0.018. This concentration will be compared with the PCB concentration of 2600 ug/g for their relative risk. In this particular case, the highest concentration of PCBs and the dioxin and furan concentration with the highest toxicological importance occur in the same sediment at NBH-14.

Computation of Relative Risk

In the following computations, PCBs will be denoted by subscript 1, and dioxins and furans will be denoted by subscript 2.

° Dermal absorption after contacting sediments by swimmers.

Upon cancelling out the common factors, the ratio of the risks can be calculated by

$$\frac{\text{Risk of PCB}}{\text{Risk of dioxins and furans}} \text{ to be denoted by } \frac{(\text{Risk})_1}{(\text{Risk})_2}$$

$$\frac{(\text{Risk})_1}{(\text{Risk})_2} = \frac{(\text{Sediment Conc.})_1 \, (\text{Potency Slope})_1 \, (\text{Absorption Factor})_1}{(\text{Sediment Conc.})_2 \, (\text{Potency Slope})_2 \, (\text{Absorption Factor})_2}$$

$$= \frac{(2600)\ (4)\ (0.05)}{(0.01686)\ (0.018)\ (3\text{x}10^5)\ (0.01)} = 571$$

Where the potency slope for 2,3,7,8 - TCDD is $3x10^5$ (mg/kg.day) and this value differs from the CAG value of $1.56x10^5$ because this potency slope is based on the dose rather than the absorbed fraction, the dermal absorption factors of 5% and 1% are used for PCBs, and dioxins and furans, respectively, and the potency slope for dioxins and furans is corrected by the TEF.

The above ratio indicates that the risk posed by PCBs is greater than that by dioxins and furans by 2 orders of magnitude.

- Absorption of Water Contaminant Thru Skin

  The relative risk can be similarly estimated as done for dermal absorption of sediment contaminants.

$$\frac{(\text{Risk})_1}{(\text{Risk})_2} = \frac{(\text{Conc. in Water})_1\ (\text{Potency Slope})_1}{(\text{Conc. in Water})_2\ (\text{Potency Slope})_2}$$

The estimation of the contaminant concentration in water requires the use of transport models. In this evaluation, a steady state model treating the transport of contaminant from sediment to water as a steady state process will be used. Since the contaminant in water also escapes the water body by volatilization, the contaminant concentration in water is inversely proportional to the mass transfer cefficient at the water-air interface (or is proportional to the resistance for volatilization at the water-air interface), inversely proportional to the contaminant partition coefficient between sediment and water, and directly proportional to the concentration in sediment. The detail discussion of the transport model and its derivation are not presented here.

The estimation of the mass transfer coefficient at the water-air interface requires the use of Henry's law constants. The two-resistance theory provides the mass transfer coefficient approximately as 1.1 cm/hr for PCBS and as 0.73 cm/hr for dioxins and furans. The sediment - water partition coefficients for PCBs, and dioxins and furans used in this estimation are 1000 L/kg, and 4680 L/kg, respectively. These partition coefficients are used as an approximation, and can vary depending upon the type of sediment.

Substitution of these values into the ratio formula for the relative risk yields

$$\frac{(\text{Risk})_1}{(\text{Risk})_2} = \frac{(1/1.1)(1/1000)(2600)(4)}{(1/0.73)(1/4680)(0.01686)(0.018)(3x10^5)}$$

$$= 354$$

The above value also shows that the risk by PCBs is about 2 orders magnitude higher than dioxins and furans.

- Intake of Bioaccumulated Fish

The Bioaccumulation factor from sediment to fish BCF is dependent upon the organic carbon content in sediment, lipid content in fish, and approach to equilibrium in transport of contaminant from sediment to fish. For the same sediment and fish under consideration, BCF cancels out also. Hence

$$\frac{(\text{Risk})_1}{(\text{Risk})_2} = \frac{(\text{Conc. in Sediment})_1\ (\text{Potency Slope})_1}{(\text{Conc. in Sediment})_2\ (\text{Potency Slope})_2}$$

$$= \frac{(2600)(4)}{(0.01686)(0.018)(3\text{x}10^5)}$$

$$= 114$$

This also shows that PCBs poses risk about 2 orders of magnitude higher than dioxins and furans.

° Air Inhalation

Sediment will release the contaminants into water from where the contaminants are volatilized into the atmosphere. There are many factors affecting the volatilization rate. Specific models will not be discussed here. However, as stated before, it can be noted that the volatilization rate is reduced by high resistance for transfer at the water-air interface (or inversely propotional to the mass-transfer coefficient). Also the volatilization rate increases as the concentration in water increases. This increase in concentration in water will be facilitated by a higher concentration in sediment and a lower value of sediment-water partition coefficient. Since the ambient air concentration is directly proportional to emission rate, the proportionality can be summarized as follows:

Ambient Air Concentration is proportional to Volatilization Rate, which is proportional to

(Water-Air Mass Transfer Coefficient)(Concentration in Water), which is proportional to

(Inverse of Sediment-Water Partition Coefficient)

(Concentration in Sediment)

Hence, the relative importance of risks between PCBs and dioxins and furans can be estimated by

$$\frac{(\text{Risk})_1}{(\text{Risk})_2} = \frac{(\text{Ambient Air Conc.})_1\ (\text{Potency Slope})_1}{(\text{Ambient Air Conc.})_2\ (\text{Potency Slope})_2}$$

$$= \frac{(1/1000)(2600)(4)}{(1/4680)(0.01686)(0.018)(3\text{x}10^5)} = 535$$

Here again, PCBs are the dominant compounds exhibiting risk higher than that posed by dioxins and furans.

Conclusion

In all four pathways considered (dermal absorption of sediment contaminants, dermal absorption of water contaminants, ingestion of bioaccumulated fish, and vapor inhalation), the relative risk of PCBs is higher than dioxins and furans for the sediments at New Bedford Harbor. The cleanup effort can be focused on reducing the risk posed by the presence of PCBs at present. However, the concentration of dioxins and furans in sediments should also be reduced to the acceptable level at the same time when the remedial action for PCBs is implemented.

Estimation of total equivalency factor (TEF) for Polychlorinated dibenzodioxin and dibenzofuran concentrations in New Bedford Harbor sediments, relative to 2,3,7,8-tetrachlorodibenzodioxin

CONGENER	Relative Potency Factor (RPF)	STATION NBH-5 Conc. (pg/g)	Conc. X RPF	NBH-12 Conc. (pg/g)	Conc. X RPF	NBH-14 Conc. (pg/g)	Conc. X RPF	NBH-15 Conc. (pg/g)	Conc. X RPF
Dibenzodioxin									
2378*	1	n. d. n. d.	0	n. d. n. d.	0	4 4	4	n. d. n. d.	0
12378	0.5	n. d. n. d.	0	21 n. d.	10.5	21 28	14	n. d. n. d.	0
123478	0.04	n. d. n. d.	0	n. d. n. d.	0	n. d. n. d.	0	n. d. n. d.	0
123678	0.04	22 25	1	65 72	2.88	137 81	5.48	26 38	1.52
123789	0.04	17 20	0.8	52 55	2.2	70 70	2.8	n. d. n. d.	0
1234678	0.001	534 1570	1.57	n. d. 905	0.905	1130 1010	1.13	324 278	0.324
12346789	0	4030 4010	0	7370 6530	0	6100 5510	0	1490 1390	0
Dibenzofuran									
2378	0.1	691 789	78.9	1380 1440	144	1220 1130	122	10 10	1
2367	0.001	289 299	0.299	1250 980	1.25	916 892	0.916	7 5	0.007
3467	0.001	n. d. 37	0.037	272 289	0.289	270 281	0.281	n. d. 2	0.002
12378	0.1	348 358	35.8	430 389	43	516 484	51.6	n. d. n. d.	0
23478	0.1	71 69	7.1	313 279	31.3	597 565	59.7	n. d. n. d.	0
23467	0.1	37 37	3.7	n. d. 151	15.1	147 176	17.6	n. d. n. d.	0
123478	0.01	n. d. 32	0.32	316 310	3.16	1510 1340	15.1	n. d. 17	0.17
123467	0.01	29 32	0.32	289 227	2.89	470 428	4.7	60 64	0.64
123678	0.01	n. d. 22	0.22	196 179	1.95	818 730	8.18	n. d. n. d.	0
123789	0.01	n. d. n. d.	0	n. d. n. d.	0	n. d. n. d.	0	n. d. n. d.	0
234678	0.01	n. d. 7	0.07	45 38	0.45	119 116	1.19	n. d. n. d.	0
1234678	0.01	152 397	0.379	853 592	0.853	1240 1240	1.24	112 131	0.131
1234789	0.01	n. d. n. d.	0	182 151	0.182	305 281	0.305	26 n. d.	0.026
12346789	0	218 228	0	671 595	0	1230 1070	0	138 209	0
Total Conc. Of Dioxins & Furans		7954		14848		16863		2318	
Summation of Conc. X RPF			130.4		260.5		305.4		3.51
TEF for Dioxins and Furans		0.0164		0.0175		0.018		0.0015	

* – Numbers refer to the positions of chlorines on the compound.

n. d. – Not detected.